

# VIBRATION GENERATING DEVICE OF SMALL WIRELESS MACHINE

## BACKGROUND OF THE INVENTION

### [Technical Field of the Invention]

The present invention relates to a vibration generating device used for a call or the like of a small wireless machine, for example, a portable or mobile telephone.

### [Prior Art]

In recent years, as a kind of a small wireless machine, such as a paging system small wireless calling machine, a PHS, or a portable, mobile telephone, a machine of a type having a built-in vibration generating device made by eccentrically coupling a vibrator of high specific gravity metal to a rotating shaft of a motor becomes popular. According to the small wireless calling machine or the like having such a built-in vibration generating device, instead of generation of a ringing tone, a vibration is generated by the rotation of the vibrator so that it is possible to confirm reception without being known to another person even in, for example, a crowd or a meeting.

Conventionally, the vibration generating device of this kind of small wireless machine is constructed such that a vibrator formed into a non-cylindrical shape is integrally coupled with a rotating shaft of a small motor connected to a signal generating circuit of the small wireless machine.

This vibrator is made of a high specific gravity metal molded by a powder metallurgical method, a cylindrical boss portion is integrally formed at an eccentric load portion of a substantially fan-shaped section, a rotating shaft is inserted into an attachment hole formed in the boss portion, and the boss portion is plastically deformed by caulking, so that the boss portion and the rotating shaft are made close to each other and it is integrally coupled to the rotating shaft.

According to the conventional vibration generating device like this, since the vibrator itself is caulked and is directly coupled to the rotating shaft, as compared with another conventional one in which a vibrator is fixed to a rotating shaft through an adhesive or other coupling parts, there is a merit that it becomes possible to reduce the number of parts.

However, in the above conventional vibration generating device, since the attachment hole must be formed in the inside of the cylindrical boss portion of the vibrator, there has been a problem that when the vibrator is molded by pressing a powder raw material, it is difficult to fill the powder raw material especially in a shaping die portion of the boss portion having a thin outer periphery, and the yield of the vibrator is lowered.

Besides, for the purpose of satisfying a demand for miniaturization in recent years, an attempt has been made to

form the vibrator itself to be small. However, since the boss portion around the attachment hole becomes very thin, there has been also another problem that when caulking is made by a large force, a crack is likely to be generated, and on the other hand, if the caulking force is low, a desired pull-out strength can not be obtained, with the result that the adjustment of the caulking force becomes difficult.

Then, as another conventional vibration generating device, there has been a proposal that as shown in FIG. 10 and FIG. 11, a groove portion 4 in which a rotating shaft 3 is fitted is formed at the center portion of an eccentric load portion 2 of a vibrator 1, side walls 5 which become both side edge portions of the groove 4 are integrally formed by bulging from the eccentric load portion 2 along the groove portion 4. The center portions of tip portions of the side walls 5 in the axial line direction are caulked from an opening side of the groove portion 4 to a bottom side by a caulking punch 7 in which its tip end is shaped into an R shape (or round shape) or a rectangular parallelepiped shape, so that it is integrally coupled to the rotating shaft 3.

According to the conventional vibration generating device described above, there are merits that molding is easier than the vibrator including the boss portion in which the attachment hole is formed, so that manufacture yield can be improved, and even in the case where the vibrator 1 itself

becomes small, as compared with the case where the thin portion such as the outer periphery of the boss portion is caulked, there is little fear that a crack is generated.

However, in the conventional vibration generating device shown in FIGS. 10 and 11, when the tip portion end surfaces of the side walls 5 are caulked, the whole width dimensions from the sides of the groove 4 to the sides of outer peripheries 6 are crushed and, therefore, a high caulking force is required. However, since the rigidity of the portions of the side walls 5 at the side of the groove 4 is high through the rotating shaft 3, when plastic deformation is made, bulging is mainly caused toward the sides of the outer peripheries 6 which become free ends, and as a result, there has been a problem that a high pull-out strength can not be obtained. Besides, as a result the high caulking force is required, when an attempt to increase a tungsten content is made to obtain a desired vibration even in the case where the vibrator 1 is made small in diameter, it becomes brittle in material, so that there has also been a problem that a crack is likely to be generated in the caulked side walls 5.

#### SUMMARY OF THE INVENTION

The present invention has been made in view of the above, and a principal object of the present invention is to provide an improvement in a vibration generating device for a small

wireless machine.

Another object of the present invention is to provide a vibration generating device of a small wireless machine in which manufacture of a vibrator is easy, the vibrator can be coupled to a rotating shaft of a motor at a high pull-out strength even by a low caulking force, and the whole device can be further miniaturized.

According to a first aspect of the invention there is provided a vibration generating device of a small wireless machine includes a vibrator integrally coupled to a rotating shaft of a motor, wherein a groove portion in which the rotating shaft is fitted is formed in an eccentric load portion, side walls bulging from the eccentric load portion and forming both side edge portions of this groove portion are formed, and a portion of a tip portion end surface of this side wall except an outer peripheral portion of the side wall and at a side of the groove portion is caulked from an opening side of the groove portion to a bottom side, so that the vibrator is integrally coupled to the rotating shaft.

Besides, according to a second aspect of the invention there is provided a vibration generating device of a small wireless machine in which a vibrator is integrally coupled to a rotating shaft of a motor, wherein an eccentric load portion is formed into a truncated fan shape in which a center angle is less than  $180^{\circ}$ , so that it has a flat surface at a rotation

center side, a groove portion in which the rotating shaft is fitted is formed in the flat surface, side walls forming both side edge portions of this groove portion are formed, a portion of the flat surface except an outer peripheral side portion of the side wall and at a side of the groove portion is caulked from an opening side of the groove portion to a bottom side, so that the vibrator is integrally coupled to the rotating shaft.

Further, according to a third aspect of the invention, which is a modification of the first aspect or second aspect of the invention, there is provided a vibration generating device of a small wireless machine, wherein a caulked portion formed into a concave shape in the tip portion end surface of the first aspect or the flat surface of the second aspect, respectively, of the invention by caulking from the opening side of the groove portion to the bottom side is formed so that a length dimension at the side of the groove in an axial line direction is longer than a length dimension at an outer peripheral side.

In the fourth aspect of the invention, in a width dimension  $W$  of the tip portion end surface or the flat surface as recited in any one of the first to third aspects, from the side of the groove to the outer peripheral side, a range of  $0.25 W$  to  $0.9 W$  from an edge portion at the side of the groove is caulked.

Further, in the fifth aspect of the invention, the groove portion of the vibrator as recited in any one of the first to fourth aspects is formed to have such a size as to internally contain a range exceeding a center angle of  $180^\circ$  of the rotating shaft, and an opening width  $W_1$  of the groove portion is set so that a ratio ( $W_1/D$ ) to a diameter  $D$  of the rotating shaft of the motor is in a range of 0.70 to 0.95.

In the vibration generating device of the small wireless machine as recited in any one of the first to fifth aspects of the invention, the rotating shaft of the motor is fitted in the groove portion, and in the tip portion end surfaces or the flat surfaces of the side walls forming both the side edge portions of this groove portion, the portion except the outer peripheral side portion and at the side of the groove is caulked to the bottom side of the groove portion, so that as compared with the conventional vibration generating device shown in FIG. 10 and FIG. 11, it becomes possible to couple the vibrator to the rotating shaft by a lower caulking force. At this time, the outer peripheral portion of the side wall which is not caulked, functions as a wall portion against the plastic deformation in the caulked portion, and consequently, the greater part of the caulked portion is bulged to the groove side. Then, the vibrator is firmly fixed to the rotating shaft by three points of the bottom portion of the groove portion, and both the bulged side walls. Thus, according to the vibration

generating device of the present invention, the manufacture of the vibration generating device is easy, and further, it is possible to couple the vibrator to the rotating shaft of the motor at a high pull-out strength even by a lower caulking force.

From the above, according to the vibration generating device of the present invention (as recited in any one of the first to fifth aspects), since the vibrator can be firmly fixed to the rotating shaft of the motor by a lower caulking force than the prior art, it is possible to realize the miniaturization and lightening of the vibrator, and the miniaturization and lightening of the vibration generating device and the whole of the small wireless machine. Besides, as a result the caulking load can be made small and the generation of a crack of the vibrator can be prevented, the productivity of the vibration generating device is improved, and it becomes possible to improve the vibration efficiency by realization of the high specific gravity of the vibrator.

Here, especially in the third aspect of the invention described above, the length dimension of the caulked portion in the axial line direction at the side of the groove where most portions are bulged to the side of the rotating shaft becomes larger than at the peripheral side which functions as the wall portion when the caulked portion is plastically deformed, so that the vibrator can be coupled to the rotating

shaft of the motor at a high pull-out strength by a lower caulking force. In addition, it becomes possible to use the caulking punch which can be easily manufactured and has a circular shape in cross section, and the use life of the caulking punch can be greatly elongated.

A fourth aspect of the invention is based upon any one of the first to third aspects of the invention described above. Namely, in the tip portion end surface or the flat surface of the side wall, when the portion except the outer peripheral side portion and at the groove side is caulked to the bottom side of the groove portion, in the width dimension  $W$  of the tip portion end surface or the flat surface from the groove side to the outer peripheral side, it is preferable to caulk the range of  $0.25 W$  to  $0.9 W$  from the edge portion of the side of the groove portion. At this time, in the case where the caulking width dimension is small, it is sufficient if the caulking length dimension in the axial line direction is made large, and on the contrary, in the case where the caulking width dimension is large, even if the caulking length dimension in the axial line direction is small, a sufficient pull-out strength can be obtained. The range of caulking is limited to the range of  $0.25 W$  to  $0.9 W$  because, if the range is smaller than  $0.25 W$ , it becomes difficult to obtain a sufficient plastic deformation amount to firmly fix the vibrator to the rotating shaft of the motor, while if the range exceeds  $0.9 W$ , the

foregoing function as the wall portion against the plastic deformation of the caulked portion is decreased, and as a result, the outer peripheral portion is also forcibly deformed outward and therefore the pull-out strength is lowered.

Besides, the shapes of the side walls may be formed so that the whole of the groove portion becomes U-shaped by erecting the side walls from both the side edges. In this case, in the state where the rotating shaft is fitted in the groove portion, the rotating shaft is internally contained in the groove portion within the range of a center angle of  $180^\circ$ . On the other hand, like the fifth aspect of the invention, when the groove portion of the vibrator is formed to have such a size that the range of the center angle of  $180^\circ$  or more of the rotating shaft is internally contained, and the opening width  $W_1$  of the groove portion is set so that the ratio ( $W_1/D$ ) to the diameter  $D$  of the rotating shaft becomes in the range of 0.70 to 0.95, by the plastic deformation of the side wall after caulking, it is possible to fill the opening portion of the groove portion more effectively and to firmly fix the vibrator, so that it is preferable.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view showing a caulking state according to a first embodiment of the present invention.

FIG. 2 is a longitudinal sectional view of a vibrator

of FIG. 1.

FIG. 3 is a perspective view showing the first embodiment of the present invention.

FIG. 4 is a front view showing the shape of a vibrator according to a second embodiment of the present invention.

FIG. 5 is a front view showing a state where the vibrator of FIG. 4 is caulked.

FIG. 6 is a front view showing the shape of a vibrator according to a third embodiment of the present invention.

FIG. 7 is a longitudinal sectional view of the vibrator shown in FIG. 6.

FIG. 8 is a perspective view showing a fourth embodiment of the present invention.

FIG. 9 is a perspective view showing a modified example of the fourth embodiment.

FIG. 10 is a front view showing a caulking state in a conventional prior art vibration generating device.

FIG. 11 is a perspective view showing the conventional prior art vibration generating device caulked as shown in FIG. 10.

#### PREFERRED EMBODIMENTS OF THE INVENTION

(First Embodiment)

FIGS. 1 to 3 shows a vibrator 10 according to a first embodiment of the present invention. The vibrator 10, which

is made of a high specific gravity metal molded by a powder metallurgical technique, has a substantially fan-shaped cross section with an axial line 0 as the center, and the whole fan-shaped portion eccentric from the axial line 0 becomes or serves as an eccentric load portion 11. In the vibrator 10, a groove portion 13 in which a rotating shaft 12 of a motor is fitted and which has a bottom portion of a semicircle almost equal to the diameter of the rotating shaft 12 is formed at the center portion of an outer peripheral arc which depicts the fan shape of the eccentric load portion 11. Further, side walls 14 which bulge from the eccentric load portion 11 in parallel with each other and become opposed side edge portions of the groove 13 are integrally formed at both the side edge portions of the groove portion 13. In this kind of vibrator 10, generally, an arc radius of the eccentric load portion 11 is as very small as several mm, and consequently, it is difficult to distinguish between vibrators of different sizes, so that concave identification marks 16 of various shapes (circle in the drawing) indicating the size of the vibration generating device 10 are formed at both end surfaces of the eccentric load portion 11.

Then, in a tip portion end surface 14a of the side wall 14, and at the center portion except both end portions in the direction of the axial line 0, a portion 14c except an outer peripheral side portion 14b of the side wall 14 and at the side

of the groove 13 is caulked by a rectangular parallelepiped caulking punch 15 from an opening side of the groove 13 to a bottom side, so that the above vibrator 10 is integrally coupled to the rotating shaft 12. Here, in a width dimension  $W$  of the tip portion end surface 14a from the side of the groove portion 13 to the outer peripheral side, the portion 14c to be caulked at the side of the groove portion 13 is set in the range of  $0.25 W$  to  $0.9 W$  from the edge portion at the side of the groove 13.

Incidentally, the rotating shaft 12 can be made of stainless, for example, SUS 420 or the like. Besides, the vibrator 10 is preferably molded by using an ultra heavy alloy material of a specific gravity of about 17 to 19 g/cm<sup>3</sup>, for example, W-Ni system, W-Ni-Fe system, W-Ni-Cu system, W-Mo-Ni-Fe system, or the like and by a powder metallurgical technique. Specifically, a mixture powder of a composition made of : W powder of 89 to 98 weight %, and Ni powder of 1.0 to 11 weight %, or a mixture powder of a composition containing the W powder and Ni powder in the above range of weight %, and one or more kinds of Cu of 0.1 to 6 weight %, Fe powder of 0.1 to 6 weight %, Mo powder of 0.1 to 6 weight %, and Co powder of 0.1 to 5 weight % is or are compacted into a fan plate shape by a pressure of 1 ton/cm<sup>2</sup> to 4 ton/cm<sup>2</sup>, and this compact is liquid phase sintered in a hydrogen gas stream of a dew point of 0°C to -6°C or an ammonia decomposition gas, and thereafter,

it is further heated in the temperature range of 700°C to 1430°C  $\pm$  30°C in a vacuum, neutral or reducing atmosphere, and then, a heat treatment of rapidly cooling it to at least 300°C at a cooling rate of 40°C/min or more is performed.

In the composition of the vibrator 10 like this, when the W (tungsten) content exceeds 98 weight %, the specific gravity becomes high although the malleability (or ductility) is lowered, and in the case where it is less than 89 weight %, a predetermined specific gravity can not be obtained, and it becomes disadvantageous as this kind of vibrator. Besides, also in the case where the N (nickel) content exceeds 11 weight %, a predetermined specific gravity can not be obtained, and in the case where it is less than 1.0 weight %, sintering does not proceed. Further, although Co (cobalt) has the same effect as Ni, when it is less than 0.1 weight %, a sufficient effect of the addition can not be obtained, and on the other hand, even if it exceeds 5 weight %, an adequate effect can not be obtained and the manufacture becomes uneconomical. When the Cu powder and Fe powder are contained, although a sintering temperature can be lowered, a predetermined specific gravity can not be obtained in a range over the above upper limit value.

According to the vibration generating device of the small wireless machine having the above structure of composition, the rotating shaft 12 of the motor is fitted in the groove 13, and in the tip portion end surfaces 14a of the side walls 14

forming both the side edge portions of the groove portion 13, except the outer peripheral side portion 14b, in the width dimension W from the side of the groove 13 to the outer peripheral side, the portion 14c in the range of 0.25 W to 0.9 W from the edge portion at the side of the groove 13 is caulked by the caulking punch 15 toward the bottom side of the groove 13, so that as compared with the conventional vibration generating device as shown in FIGS. 10 and 11, it is possible to couple the vibrator to the rotating shaft by a lower caulking force.

At this time, since the outer peripheral portion 14b of the side wall, which is not caulked, functions as a wall portion against the plastic deformation in the caulked portion 14c, the greater part of the caulked portion 14c is bulged to the side of the groove 13, and consequently, the vibrator 10 can be firmly fixed to the rotating shaft 12 by three points of the bottom portion of the groove 13, and both the bulged side walls. Thus, manufacture of the vibrator 10 is easy, and the vibrator can be coupled to the rotating shaft of the motor at a high pull-out strength even by a low caulking force.

According to the vibration generating device described above, since the vibrator 10 can be firmly fixed to the rotating shaft 12 by a lower caulking force than the prior art, miniaturization and lightening of the vibrator 10 itself, and further, miniaturization and lightening of the vibration

generating device and the whole of the small wireless machine can be realized. Besides, since the caulking load is made small and the generation of a crack in the vibrator 10, especially at the side wall 14 can be prevented, it becomes possible to increase the productivity of the vibration generating device and to improve the vibration efficiency through realization of the high specific gravity of the vibrator 10.

[Experiment]

An experiment was made in which the pull-out strength of the vibrator 10 fixed to the rotating shaft 12 by the caulking according to the present invention was compared with the pull-out strength of the conventional vibrator 1 fixed to the rotating shaft 3 by the conventional caulking shown in FIGS. 10 and 11. In the comparison experiment, by using the vibrators 1 and 10 and the rotating shafts 3 and 12 respectively having the same shape, five vibration generating devices were produced in each group.

In the above vibrators 1 and 10 used for the experiment, the outer diameter of each of the eccentric load portions 2 and 11 was 3 mm, the length in the direction of the axial line O was 5 mm, the inner diameter of each of the grooves 4 and 13 was 0.4 mm, the height dimension of each of the side walls 5 and 14 from the bottoms of the grooves 4 and 13 was 1.1 mm, the width dimension W of each of the side walls 5 and 14 was

0.7 mm, and the outer diameter dimension of each of the rotating shafts 3 and 12 was 0.8 mm.

Besides, in the conventional vibration generating device, the side wall 5 extending over the whole width dimension was crushed in a length of 2.6 mm in the axial line direction by the caulking punch 7. On the other hand, in the vibration generating device of the present invention, by using the caulking punch 15 with a width size of 1.4 mm, the range (0.43 W) of 0.3 mm of the respective side walls 14 from the side of the groove portion 13 was crushed in a length of 2.0 mm in the axial line direction.

With respect to the five vibration generating devices in each group obtained in this way, a pull-out test of the conventional vibrators 1 and the inventive vibrators 10 was carried out, and it was found that while the extracting force (kgf) was 5.3, 4.9, 5.5, 5.5, 5.4 (average 5.3) in the conventional vibration generating device, the extracting force (kgf) was 10.3, 11.0, 10.5, 10.3, 10.2 (average 10.5) in the vibration generating device of the present invention, that is, in spite of the fact that the caulking length in the axial line direction was shorter by 0.6 mm, the pull-out strength almost twice the conventional pull-out strength was obtained.

(Second Embodiment)

FIGS. 4 and 5 show a second embodiment of the present

invention, and in this vibration generating device, a groove portion 22 having a bottom portion 22a of a substantially semicircular shape is formed in an eccentric load portion 21 of a vibrator 20, and side walls 23 forming both side walls of this groove portion 22 are integrally formed so as to cover an exposed portion of a rotating shaft 24 of a motor fitted in the groove 22 with an interval from both sides in the direction of an axial line O. As a result, the groove portion 22 of the vibrator 20 is formed to have such a size as to internally contain the range of a center angle  $180^\circ$  or more of the rotating shaft 24. An opening width  $W_1$  of the groove portion 22 between the opposite side walls 23 is set so that a ratio ( $W_1/D$ ) to a diameter D of the rotating shaft 24 is in the range of 0.70 to 0.95.

As a specific example in which such a range is obtained, in the case where the diameter D (mm) of the rotating shaft 24 is 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 or 1.0, it is sufficient if the opening width  $W_1$  (mm) of the groove portion 22 between the side walls 23 is set to 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, or 0.9.

As shown in FIG. 5, in a tip portion end surface 23a of the side wall 23, and at the center portion except both ends in the direction of the axial line O, a portion 23c except an outer peripheral side portion 23b of the side wall 23 and at the side of the groove 22 is caulked by a rectangular

parallelepiped caulking punch 25 from an opening side of the groove 22 to a bottom side, so that the above vibrator 20 is integrally coupled to the rotating shaft 24. At this time, similarly to the first embodiment, in a width dimension W of the tip portion end surface 23a from the side of the groove portion 22 to the outer peripheral side, the caulked portion 23c at the side of the groove 22 is set so that it is in the range of 0.25 W to 0.9 W from an edge portion at the side of the groove 22.

Also in the vibration generating device having the above structure shown in FIGS. 4 and 5, the same function and effect as those of the first embodiment can be obtained, and especially in the vibrator 20 of the second embodiment, the groove portion 22 of the vibrator 20 is formed to have such a size as to internally contain the range of a center angle of  $180^\circ$  or more of the rotating shaft 24, and the opening width  $W_1$  of the groove portion 22 is set so that the ratio ( $W_1/D$ ) to the diameter D of the rotating shaft 24 is in the range of 0.70 to 0.95, so that the vibrator 20 is firmly fixed to the rotating shaft 24 by three points of the bottom portion 22a of the groove portion 22, and bottom portions 23d of the side walls 23. As a result, it is possible to fix the vibrator 20 to the rotating shaft 24 by a lower caulking force.

(Third Embodiment)

FIGS. 6 and 7 show a vibrator 30 of a third embodiment,

and in this vibrator 30, the whole of an eccentric load portion 31 is formed into a shape of a truncated fan-shaped cross section in which a center portion, indicated by a dotted line in the drawing, of a fan shape with a center angle of less than  $180^\circ$  is removed. By this, flat surfaces 32 are formed at the rotation center side of the vibrator 30, and a U-shaped groove portion 33 in which the rotating shaft is fitted is formed at the center of this flat portions 32. As a result, side walls 34 forming both side edge portions of the groove portion 33 are formed at both sides of this groove portion 33, and an outer peripheral surface 34a of the side wall 34 is formed into a slant flat surface shape which is continuous with an outside surface 31a of this eccentric load portion 31 and leads to an arc-shaped outer peripheral surface 31b.

Similarly to the first embodiment, in the flat surface 32 which becomes a tip portion end surface of the side wall 34, and at the center portion except both end portions in the axial line direction, a portion of the side wall 34, except a portion at the side of the outer peripheral surface 34a, at the side of the groove portion 33 is caulked by a rectangular parallelepiped caulking punch from the opening side of the groove portion 33 to the bottom side, so that the above vibrator 30 is integrally coupled to the rotating shaft. Also in this vibrator 30, in the width dimension W of the flat surface 32 from the side of the groove portion 33 to the outer peripheral

side, the caulked portion at the side of the groove 33 is set so that it is in the range of 0.25 W to 0.9 W from the edge portion at the side of the groove 33.

Also in the vibration generating device made of the above structure of the third embodiment of the invention, the same function and effect as those shown in the first embodiment can be obtained, and further, the whole of the vibrator 30 is formed into the shape having the center angle of less than  $180^\circ$  and having the truncated fan-shaped cross section in which the flat portion 32 is formed at the center portion. Therefore, there are such advantages that a metal mold shape for forming the vibrator 30 by powder molding is simplified, and manufacture becomes easy. Further, since the center of gravity can be set at a position decentered (or eccentric) from the rotating shaft to the outside, a desired vibration can also be obtained.

(Fourth Embodiment)

FIGS. 8 and 9 show a vibrator 40 according to a fourth embodiment of the invention and its modified example, respectively. The vibrator 40 has substantially the same shape as that shown in the first embodiment, and the entire of a fan-shaped portion eccentric from its axial line is an eccentric load portion 41. In the vibrator 40, a semicircular groove portion 43 in which a rotating shaft 42 of a motor is fitted and which has a bottom portion with a size substantially equal to a diameter of the rotating shaft 42 is formed at the

center portion of an outer peripheral arc which depicts the fan shape of the eccentric load portion 41. Side walls 44 bulging from the eccentric load portion 41 in parallel with each other and becoming both side edge portions of the groove 43 are integrally formed at both side edge portions of the groove portion 43.

Then, in a tip portion end surface 44a of the side wall 44, and at the center portion except both end portions in an axial line direction, a portion 44c of the side wall 44 except an outer peripheral side portion 44b and at the side of the groove 43 is caulked by a cylindrical caulking punch 45 from an opening side of the groove 43 to a bottom side, so that the above vibrator 40 is coupled to the rotating shaft 42. Here, as a result of caulking by the cylindrical caulking punch 45, the concave caulked portions 44c formed at the tip portion end surfaces 44a respectively become substantially semi-circular, and are formed so that a length dimension L in the axial line direction at the side of the groove portion 43 becomes larger than a length dimension at the outer peripheral side.

Besides, in a vibrator 40 shown in FIG. 9, at the center portion of a tip portion end surface 44a, a portion 44c' of a side wall 44 except an outer peripheral side portion 44b and at the side of a groove 43 is caulked by a caulking punch 46 in a state where a corner portion of the caulking punch 46 having a square section is positioned at the outer peripheral side,

so that it is integrally coupled to a rotating shaft 42. By this, the concave caulked portion 44c' formed by caulking with the caulking punch 46 is formed into a triangular shape having a bottom side at the side of the groove 43.

As a result, according to the above vibration generating devices shown in FIG. 8 and FIG. 9, the same function and effect as those shown in the first and second embodiments are obtained, and further, the length dimensions of the caulked portions 44c and 44c' are formed so that the dimension at the side of the groove 43 where most parts are bulged to the side of the rotating shaft 42 becomes larger than that at the outer peripheral side functioning as a wall portion when the caulked portions 44c and 44c' are plastically deformed, so that the total volume to be plastically deformed becomes small, and a high pull-out strength can be obtained by a further low caulking force. In addition, it is possible to use the caulking punch 45 which is easily manufactured and has the circular section, and it is also possible to greatly enlarge the use life of the caulking punches 45 and 46.

With respect to the vibrators 10, 20, 30 and 40 in the first to fourth embodiments of the invention, although the description has been made only on the case where the eccentric load portions 11, 21, 31, and 41 having the substantially fan-shaped section or truncated fan-shape section are formed, the invention is not limited to this, but it is possible to

use some other modified structures including eccentric load portions of various shapes, for example, a substantially semi-circular section or the like.

Besides, also with respect to the groove portions 13, 22, 33, and 43, the bottom portions are not limited to the semi-circular shape, but they can be formed into various sectional shapes, such as a substantially square section or a substantially trapezoid section.

[Effect of the Invention]

As described above, according to the vibration generating device of the small wireless machine as recited in any one of first to fifth aspects of the invention, since the vibrator can be firmly fixed to the rotating shaft of the motor by a lower caulking force than the prior art, miniaturization and lightening of the vibrator, and miniaturization and lightening of the vibration generating device and the entire of the small wireless machine can be realized, and a caulking load can be made small and the generation of a crack of the vibrator can be prevented, and consequently, the productivity of the vibration generating device can be improved, and it becomes possible to improve the vibration efficiency by realization of the high specific gravity of the vibrator.

Here, especially according to the invention as recited in the third aspect of the invention, the vibrator with a high pull-out strength can be coupled to the rotating shaft of the

motor by a further low caulking force, and further, it becomes possible to use the caulking punch which is easily manufactured and has the circular section, and the use life of the caulking punch can be greatly elongated.

Besides, according to the invention as recited in the fifth aspect of the invention, the groove portion of the vibrator is formed to have such a size as to internally contain the range of the center angle of  $180^\circ$  or more of the rotating shaft, and the opening width  $W_1$  of the above groove portion is set so that the ratio ( $W_1/D$ ) to the diameter  $D$  of the rotating shaft is in the range of 0.70 to 0.95, so that it is possible to obtain an effect that after caulking, the opening portion of the groove portion is further effectively filled by the plastic deformation of the side wall and the vibrator can be firmly fixed.